

Comparative Assessment of Ultrasound-Guided versus Conventional Caudal Epidural Block in Pediatric Anesthesia

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Abstract

Background: Caudal epidural block is one of the most commonly used regional anaesthetic techniques in paediatric patients undergoing infraumbilical surgeries. Although the conventional landmark-guided technique is widely practiced, anatomical variations may result in multiple needle attempts, failed block, and inadequate analgesia. Ultrasound guidance enables real-time visualization of the sacral anatomy and may improve the accuracy, safety, and effectiveness of caudal block.

Aim: To compare the traditionally used landmark-guided technique of caudal block with the ultrasound-guided technique in terms of intraoperative analgesia, haemodynamic parameters, time required to perform the block, and the requirement for rescue analgesia in paediatric patients.

Materials and Methods: This prospective, randomized comparative study was conducted on 150 paediatric patients aged 1–12 years, belonging to ASA physical status I and II, undergoing elective infraumbilical surgeries under general anaesthesia. Patients were randomly allocated into two groups of 75 each. Group C received conventional landmark-guided caudal block, whereas Group U received ultrasound-guided caudal block. The primary outcome measures included intraoperative analgesia, haemodynamic parameters, time required to perform the block, and the requirement for rescue analgesia. Data were analysed using the independent Student's t-test and Chi-square test. A p-value of <0.05 was considered statistically significant.

Results: The demographic characteristics of both groups were comparable. The mean time required to perform the caudal block was significantly lower in the ultrasound-guided group (3.72 ± 0.64 minutes) than in the conventional group (4.85 ± 0.88 minutes) ($p < 0.001$). Adequate intraoperative analgesia was achieved in 97.3% of patients in Group U compared with 86.7% in Group C ($p = 0.027$). Rescue analgesia was required in only 4.0% of patients in the ultrasound-guided group compared with 16.0% in the conventional group ($p = 0.014$). First-attempt block success was significantly higher in Group U (97.3%) than in Group C (81.3%) ($p = 0.002$). Intraoperative heart rate and mean arterial pressure remained more stable in the ultrasound-guided group. Procedure-related complications were fewer with ultrasound guidance, although the difference was not statistically significant.

Conclusion: Ultrasound-guided caudal block is superior to the conventional landmark-guided technique in paediatric patients undergoing infraumbilical surgeries. It provides better intraoperative analgesia, improved haemodynamic stability, shorter block performance time, higher first-attempt success, and reduced requirement for rescue analgesia. Ultrasound guidance should be considered the preferred technique whenever the necessary equipment and expertise are available.

Keywords: Caudal Block; Ultrasound Guidance; Landmark Technique; Paediatric Anaesthesia; Intraoperative Analgesia; Rescue Analgesia.

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Introduction

Caudal epidural block is one of the most commonly performed regional anaesthetic techniques in paediatric patients undergoing infraumbilical surgeries because of its simplicity, safety, and effectiveness in providing perioperative analgesia.

It is frequently used as an adjunct to general anaesthesia to reduce intraoperative analgesic requirements, improve postoperative pain control, and decrease the need for systemic opioids, thereby minimizing their associated adverse effects such as

respiratory depression, nausea, and vomiting.[1,2] Conventionally, caudal block is performed using anatomical surface landmarks to identify the sacral hiatus. Although this landmark-guided technique has been widely practiced for decades, its success largely depends on the clinician's experience and the patient's anatomical characteristics. Variations in sacral anatomy, obesity, and congenital anomalies may increase the likelihood of failed block placement, multiple needle attempts, inadvertent intravascular or subcutaneous injection, and inadequate analgesia.[3,4]

The introduction of ultrasonography into regional anaesthesia has significantly improved the accuracy and safety of peripheral nerve blocks and neuraxial procedures. Ultrasound provides real-time visualization of the sacral hiatus, sacrococcygeal ligament, caudal epidural space, needle trajectory, and spread of local anaesthetic solution, thereby enhancing procedural precision. Several studies have demonstrated that ultrasound guidance improves first-attempt success rates, reduces technical difficulties, minimizes complications, and increases the overall success of caudal block compared with the conventional landmark technique.[5–8]

Adequate intraoperative analgesia and haemodynamic stability are essential components of safe paediatric anaesthesia. Effective caudal analgesia attenuates the surgical stress response, resulting in stable heart rate and blood pressure during surgery while reducing the requirement for supplemental analgesics. Furthermore, an accurately performed caudal block provides prolonged postoperative analgesia, delays the need for rescue analgesics, and contributes to improved patient recovery and parental satisfaction.[2,9]

Despite the increasing availability of ultrasound in anaesthesia practice, the conventional landmark-guided technique continues to be widely used because of its simplicity, low cost, and familiarity among anaesthesiologists. Evidence comparing both techniques has shown variable results regarding procedural time, block success, haemodynamic parameters, and analgesic efficacy, particularly in paediatric patients undergoing infraumbilical surgeries.[3,5,10]

Therefore, further comparative studies are required to evaluate the clinical advantages of ultrasound-guided caudal block over the traditional landmark-guided approach.

Hence, the present study was conducted to compare ultrasound-guided and conventional landmark-guided techniques for caudal block in paediatric patients with respect to intraoperative analgesia, haemodynamic parameters, time required to

perform the block, and the requirement for rescue analgesia.

Material and Methods

A prospective, comparative, randomized study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee and written informed consent from the parents or legal guardians of all participating children.

A total of 150 paediatric patients aged 1–12 years, belonging to the American Society of Anesthesiologists (ASA) physical status I and II, and scheduled to undergo elective infraumbilical surgical procedures under general anaesthesia with caudal epidural block were included in the study. Patients with infection at the injection site, bleeding disorders, congenital spinal anomalies, allergy to local anaesthetics, neurological disorders, or refusal of consent were excluded.

The enrolled patients were randomly allocated into two equal groups of 75 patients each using a computer-generated randomization sequence.

Group C (Conventional Group): Caudal block was performed using the conventional landmark-guided technique.

Group U (Ultrasound Group): Caudal block was performed under real-time ultrasound guidance.

All patients underwent a detailed pre-anaesthetic evaluation before surgery. Standard fasting guidelines were followed, and routine investigations were reviewed. Upon arrival in the operating room, standard monitoring including electrocardiography, non-invasive blood pressure, pulse oximetry, and heart rate monitoring was instituted. General anaesthesia was induced according to the institutional protocol.

Following induction of anaesthesia, patients were placed in the lateral decubitus position for administration of the caudal block. In Group C, the sacral hiatus was identified using conventional anatomical landmarks, and the caudal epidural space was accessed using the standard landmark technique.

In Group U, a high-frequency linear ultrasound probe was used to identify the sacral hiatus, sacrococcygeal ligament, and caudal epidural space, and the needle was advanced under real-time ultrasound visualization. Following confirmation of correct needle placement, the predetermined volume of local anaesthetic was injected after negative aspiration.

The time required to perform the caudal block was recorded from identification of the puncture site until completion of local anaesthetic injection. Intraoperative haemodynamic parameters including

heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation were recorded at baseline and at predetermined intervals during surgery.

The adequacy of intraoperative analgesia was assessed based on haemodynamic responses to surgical stimulation. A rise in heart rate or mean arterial pressure exceeding 20% of baseline values was considered inadequate analgesia, and rescue analgesia was administered accordingly. The requirement for rescue analgesia during the intraoperative period was documented.

The primary outcome measures were intraoperative analgesic efficacy, haemodynamic stability, time required to perform the caudal block, and requirement for rescue analgesia. Secondary outcomes included the success of block placement and any procedure-related complications.

The collected data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. The independent Student's t-test was used for comparison of continuous variables, whereas the Chi-square test or Fisher's exact test was applied for categorical variables as appropriate. A p-value of <0.05 was considered statistically significant.

Results

Table 1 shows the age-wise distribution of the study participants. The majority of children belonged to the 4–6 years age group (33.3%), followed by the 7–9 years (25.3%), 1–3 years (23.3%), and 10–12 years (18.0%) age groups. The age distribution was comparable between the conventional and ultrasound-guided groups.

Table 2 compares the demographic characteristics of the two study groups. The mean age was 6.12 ± 2.94 years in the conventional group and 6.25 ± 2.81 years in the ultrasound-guided group. The mean body weight was 19.6 ± 6.1 kg and 20.1 ± 5.8 kg, respectively. Male participants predominated in both groups. No statistically significant difference was observed between the groups with respect to age, weight, or gender distribution ($p>0.05$).

Table 3 depicts the distribution of patients according to ASA physical status. Most patients in both groups belonged to ASA Grade I (72.7%), while the remaining patients were categorized as ASA Grade II (27.3%). The distribution was comparable between the groups without any statistically significant difference ($p=0.582$).

Table 4 compares the time required to perform the caudal block between the two techniques. The ultrasound-guided group required significantly less time (3.72 ± 0.64 minutes) compared with the conventional landmark-guided group (4.85 ± 0.88 minutes). The difference was statistically highly significant ($p<0.001$).

Table 5 compares the intraoperative heart rate between the two groups. Baseline heart rate was comparable in both groups. During surgery, the ultrasound-guided group demonstrated lower heart rates at 20 and 30 minutes compared with the conventional group, and the differences were statistically significant ($p<0.05$), indicating better haemodynamic stability.

Table 6 presents the comparison of mean arterial pressure between the study groups. Baseline mean arterial pressure was similar in both groups. However, significantly lower mean arterial pressure values were observed in the ultrasound-guided group at 20 and 30 minutes of surgery ($p<0.05$), reflecting improved intraoperative haemodynamic control.

Table 7 illustrates the adequacy of intraoperative analgesia. Adequate analgesia was achieved in 97.3% of patients in the ultrasound-guided group compared to 86.7% in the conventional group. Inadequate analgesia was observed more frequently in the conventional group. The difference between the groups was statistically significant ($p=0.027$). Table 8 shows the requirement for rescue analgesia during surgery. Rescue analgesia was required in 16.0% of patients in the conventional group compared with only 4.0% in the ultrasound-guided group. The ultrasound-guided technique significantly reduced the need for rescue analgesia ($p=0.014$).

Table 9 compares the first-attempt success rate of caudal block placement. Successful block placement on the first attempt was achieved in 97.3% of patients in the ultrasound-guided group compared with 81.3% in the conventional group. The difference was statistically significant ($p=0.002$), demonstrating greater procedural accuracy with ultrasound guidance.

Table 10 summarizes the procedure-related complications observed during the study. Most patients in both groups experienced no complications. Blood aspiration, subcutaneous injection, and failed block were more frequently encountered in the conventional group, whereas only one patient in the ultrasound-guided group had blood aspiration. Although the overall complication rate was lower in the ultrasound-guided group, the difference was not statistically significant ($p=0.094$).

Table 1: Distribution of study participants according to age

Age group (years)	Group C (n=75)	Group U (n=75)	Total (n=150)
1–3	18 (24.0%)	17 (22.7%)	35 (23.3%)
4–6	24 (32.0%)	26 (34.7%)	50 (33.3%)
7–9	20 (26.7%)	18 (24.0%)	38 (25.3%)
10–12	13 (17.3%)	14 (18.7%)	27 (18.0%)
Total	75 (100%)	75 (100%)	150 (100%)

Table 2: Comparison of demographic characteristics between the two groups

Variable	Group C (n=75)	Group U (n=75)	p-value
Age (years) (Mean $\pm$ SD)	6.12 $\pm$ 2.94	6.25 $\pm$ 2.81	0.781
Weight (kg) (Mean $\pm$ SD)	19.6 $\pm$ 6.1	20.1 $\pm$ 5.8	0.624
Male	46 (61.3%)	44 (58.7%)	0.742
Female	29 (38.7%)	31 (41.3%)	

Table 3: Distribution according to ASA physical status

ASA Grade	Group C (n=75)	Group U (n=75)	Total (n=150)	p-value
I	53 (70.7%)	56 (74.7%)	109 (72.7%)	0.582
II	22 (29.3%)	19 (25.3%)	41 (27.3%)	
Total	75	75	150	

Table 4: Comparison of time required to perform caudal block

Group	Mean $\pm$ SD (minutes)	t-value	p-value
Group C	4.85 $\pm$ 0.88	8.94	<0.001*
Group U	3.72 $\pm$ 0.64		

Table 5: Comparison of intraoperative heart rate (beats/min)

Time interval	Group C (Mean $\pm$ SD)	Group U (Mean $\pm$ SD)	p-value
Baseline	106.8 $\pm$ 9.5	105.9 $\pm$ 9.2	0.564
10 minutes	104.3 $\pm$ 8.8	101.7 $\pm$ 8.1	0.068
20 minutes	103.8 $\pm$ 8.6	99.8 $\pm$ 7.5	0.012*
30 minutes	103.2 $\pm$ 8.1	99.2 $\pm$ 7.1	0.008*

Table 6: Comparison of mean arterial pressure (mmHg)

Time interval	Group C (Mean $\pm$ SD)	Group U (Mean $\pm$ SD)	p-value
Baseline	71.8 $\pm$ 6.2	72.1 $\pm$ 5.8	0.758
10 minutes	69.7 $\pm$ 5.5	68.2 $\pm$ 5.1	0.093
20 minutes	69.2 $\pm$ 5.2	66.8 $\pm$ 4.8	0.009*
30 minutes	68.9 $\pm$ 5.0	66.3 $\pm$ 4.5	0.004*

Table 7: Comparison of intraoperative analgesia

Analgesia	Group C (n=75)	Group U (n=75)	p-value
Adequate	65 (86.7%)	73 (97.3%)	0.027*
Inadequate	10 (13.3%)	2 (2.7%)	
Total	75	75	

Table 8: Requirement of rescue analgesia

Rescue analgesia	Group C (n=75)	Group U (n=75)	p-value
Required	12 (16.0%)	3 (4.0%)	0.014*
Not required	63 (84.0%)	72 (96.0%)	
Total	75	75	

Table 9: First-attempt successful block

First-attempt success	Group C (n=75)	Group U (n=75)	p-value
Yes	61 (81.3%)	73 (97.3%)	0.002*
No	14 (18.7%)	2 (2.7%)	
Total	75	75	

Table 10: Procedure-related complications

Complication	Group C (n=75)	Group U (n=75)	p-value
No complication	69 (92.0%)	74 (98.7%)	0.094
Blood aspiration	3 (4.0%)	1 (1.3%)	
Subcutaneous injection	2 (2.7%)	0 (0.0%)	
Failed block	1 (1.3%)	0 (0.0%)	
Total			

Discussion

Caudal epidural block remains one of the most widely accepted regional anaesthetic techniques for paediatric patients undergoing infraumbilical surgeries because it provides effective intraoperative and postoperative analgesia with a favourable safety profile. In recent years, ultrasound guidance has been increasingly incorporated into regional anaesthesia to improve the precision of needle placement and reduce procedure-related complications. The present study compared ultrasound-guided and conventional landmark-guided techniques of caudal block with respect to intraoperative analgesia, haemodynamic parameters, time required to perform the block, and the requirement for rescue analgesia.

The demographic characteristics of the study population were comparable between the two groups. There was no statistically significant difference in age, weight, gender distribution, or ASA physical status, indicating that both groups were well matched and that the observed differences in clinical outcomes were attributable to the technique employed rather than baseline characteristics. Similar demographic comparability has been reported in previous comparative studies evaluating caudal block techniques in children.[11,12]

The present study demonstrated that the ultrasound-guided technique required significantly less time for successful completion of the caudal block than the conventional landmark-guided technique. Although ultrasound requires initial equipment setup, direct visualization of the sacral hiatus and needle advancement facilitates accurate needle placement and minimizes repeated attempts, thereby shortening the overall procedure time. Similar findings were reported by Gautam et al., who observed significantly reduced block performance time with ultrasound guidance compared to the conventional approach.[13] Ahiskalioglu et al. also reported that ultrasound guidance improved procedural efficiency and increased first-attempt success rates in paediatric caudal blocks.[14]

Adequate intraoperative analgesia was achieved in a significantly greater proportion of patients in the ultrasound-guided group. Accurate deposition of local anaesthetic into the caudal epidural space under real-time visualization ensures more reliable

neural blockade, thereby reducing inadequate analgesia resulting from incorrect needle placement. These findings are consistent with previous studies demonstrating superior analgesic efficacy of ultrasound-guided caudal blocks because of improved accuracy and appropriate spread of local anaesthetic.[13,14]

Haemodynamic parameters remained stable in both groups throughout surgery; however, patients receiving ultrasound-guided caudal block exhibited significantly lower intraoperative heart rate and mean arterial pressure during surgical stimulation. These observations suggest improved attenuation of the surgical stress response owing to more effective analgesia. Similar improvements in haemodynamic stability have been reported in comparative studies evaluating ultrasound-guided regional anaesthesia in paediatric patients.[12,14]

The requirement for rescue analgesia was significantly lower in the ultrasound-guided group compared with the conventional group. Better localization of the caudal epidural space and more predictable spread of local anaesthetic provide more consistent analgesia, thereby reducing the need for supplemental analgesics during surgery. Malik et al. similarly reported a significantly lower requirement for rescue analgesia among children receiving ultrasound-guided caudal blocks than those receiving conventional landmark-guided blocks.[15]

Another important finding of the present study was the significantly higher first-attempt success rate observed with ultrasound guidance. Direct visualization of anatomical structures and needle advancement reduces technical difficulties and increases procedural accuracy. These findings are in agreement with those reported by Ahiskalioglu et al. and Gautam et al., both of whom demonstrated superior first-pass success with ultrasound-guided caudal block compared with the landmark technique.[13,14]

Procedure-related complications such as blood aspiration, subcutaneous injection, and failed block were less frequent in the ultrasound-guided group, although the difference did not reach statistical significance. Nevertheless, ultrasound guidance permits visualization of the sacral anatomy and local anaesthetic spread, thereby reducing the likelihood of inadvertent needle placement and potentially improving patient safety. Similar

observations have been documented by previous investigators, who concluded that ultrasound guidance enhances procedural safety and minimizes complications during paediatric regional anaesthesia.[11,12]

Overall, the findings of the present study support the growing body of evidence favouring ultrasound-guided caudal block over the conventional landmark-guided technique. Ultrasound guidance provided superior procedural accuracy, improved intraoperative analgesia, greater haemodynamic stability, shorter block performance time, and reduced requirement for rescue analgesia. These advantages may contribute to improved perioperative outcomes and greater safety in paediatric patients undergoing infraumbilical surgical procedures.

The present study has certain limitations. It was conducted at a single tertiary care centre with a relatively limited sample size, which may restrict the generalizability of the findings. Long-term postoperative pain assessment, parent satisfaction, and cost-effectiveness of ultrasound guidance were not evaluated. Future multicentre randomized controlled trials with larger sample sizes and extended postoperative follow-up are recommended to further establish the clinical benefits and economic feasibility of ultrasound-guided caudal block in paediatric anaesthesia.

Conclusion

The present study concludes that ultrasound-guided caudal block is superior to the conventional landmark-guided technique in paediatric patients undergoing infraumbilical surgeries. Ultrasound guidance significantly reduced the time required to perform the block, improved intraoperative analgesia, enhanced haemodynamic stability, increased first-attempt success, and decreased the requirement for rescue analgesia. In addition, procedure-related complications were fewer with ultrasound guidance. Therefore, whenever ultrasound equipment and trained personnel are available, ultrasound-guided caudal block should be considered the preferred technique for providing safe and effective perioperative analgesia in paediatric patients.

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